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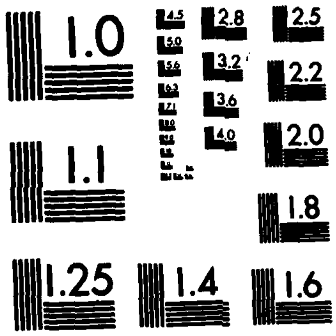

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The SDS Dosimeter

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Prepared for

SPACE DIVISION
AIR FORCE SYSTEMS COMMAND
Los Angeles Air Force Station
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This report has been reviewed by the Public Affairs Office (PAS) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication. Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

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Radiation Dose in Electronics
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report summarizes space-radiation dosimeter units -3A, -1B, and -2B designed and tested by The Aerospace Corporation Space Sciences Laboratory to be flown aboard SDS satellites. Two circular surface barrier silicon detectors with a nominal 4.8 mm^3 volume are located, with electronics, inside of the main mission electronics box. Each detector measures the total energy deposited in the depleted (active) volume by charged particles and photons. The detectors are passively cooled in order to keep the system noise well below the electronic energy threshold set at 66 keV. A backup instrument also

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19. KEY WORDS (Continued)

10 to the -9th power

20. ABSTRACT (Continued)

with 66 keV threshold has been included in the system. A special gated integrating circuit associated with each of the detectors monitors the deposited energy, producing output pulses each of which corresponds to a dose of approx. ~~$\sim 2.7 \times 10^{-6}$~~ rads. The maximum measurable dose rate is 0.27 rads/sec. The minimum detectable dose rate is 5.4×10^{-9} rads/sec. The pulses are counted by a scaler whose contents are read out by the spacecraft telemetry system. Maximum storage capacity of the scaler corresponds to an accumulated dose of 0.185 megarad. The instrument package weighs 1 lb., 1.51 oz. and uses 0.360 watts of power. Only one dosimeter of the pair in the instrument package draws power at a given time.

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CONTENTS

FIGURES

TABLE

1 Introduction

The purpose of the Mission 46B dosimeter (hereafter referred to as the dosimeter) is to measure the radiation dose in silicon under aluminum shielding. The interest in such data was engendered by the discovery of the "softness" of current microelectronics circuitry to radiation coupled with the present substantial uncertainty and controversy concerning the natural energetic electron dose received by a satellite in a Molniya orbit. Direct measurement of this dose correlated with performance of on-board circuitry is therefore of crucial importance in providing data for planning of future missions.

The dosimeter, designed by The Aerospace Corporation Space Sciences Laboratory, uses technology proven by flight aboard many USAF and NASA satellites. Each instrument package consists of two separate, single-detector units. These omnidirectional sensors use small circular surface barrier silicon detectors mounted inside of the cover of the Mission 46B electronics box and behind a 50 mil thickness of aluminum. Figure 1 is a picture of an instrument package containing the -1B and -3A dosimeters. The dosimeter directly measures the ionization in the silicon disc caused by the natural radiation — that is, the radiation dose. Each instrument package weighs 1 lb 1.51 oz and uses 0.36C watts of power. All three dosimeter units delivered so far are identical with the exception that one instrument package has only one dosimeter. The calibrations are identical.

2. Measurement Technique

A block diagram of the electronic system associated with one of the two silicon detectors is shown in Figure 2. A particle passing through the active

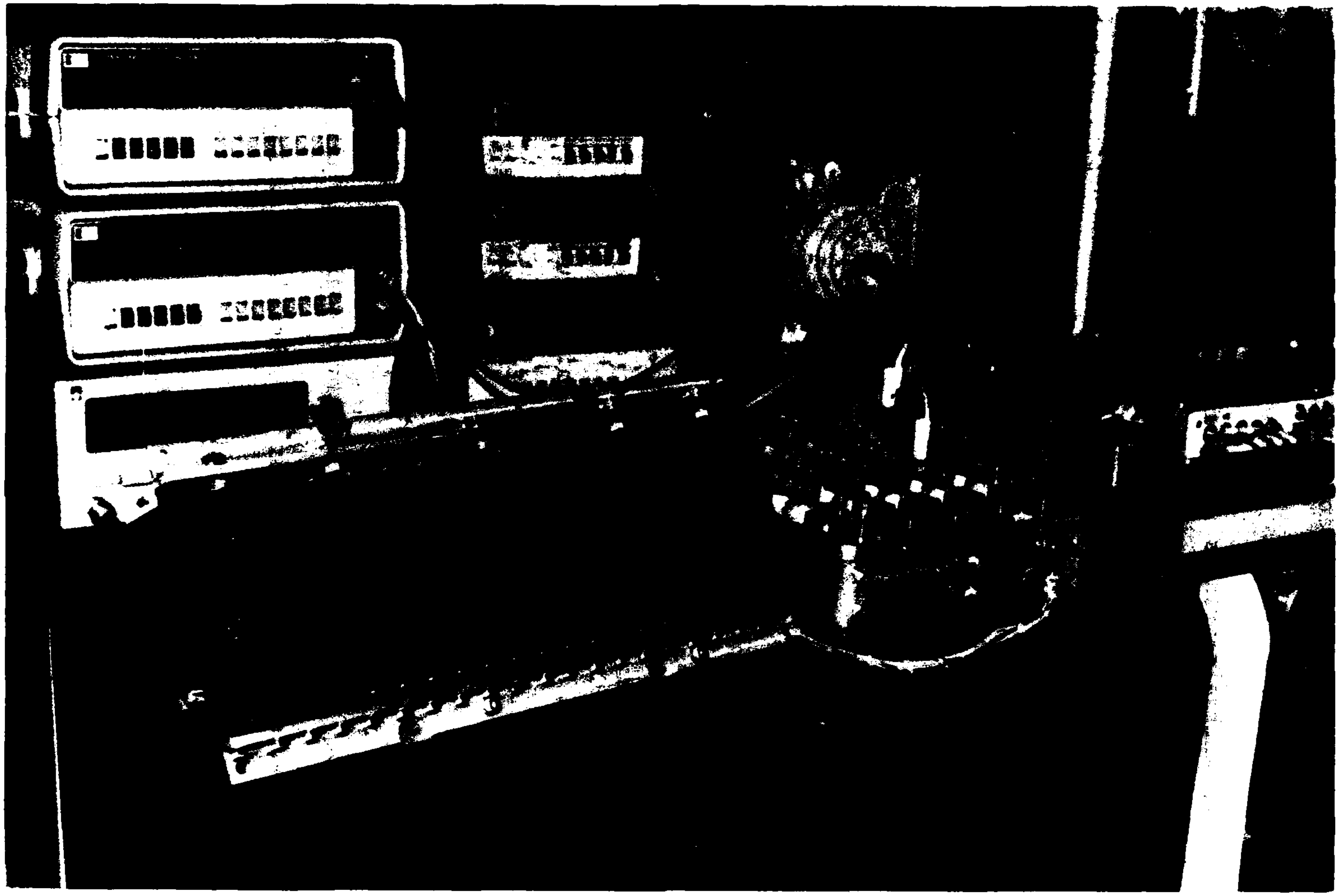

FIGURE 1. Photograph of a Dosimeter Unit

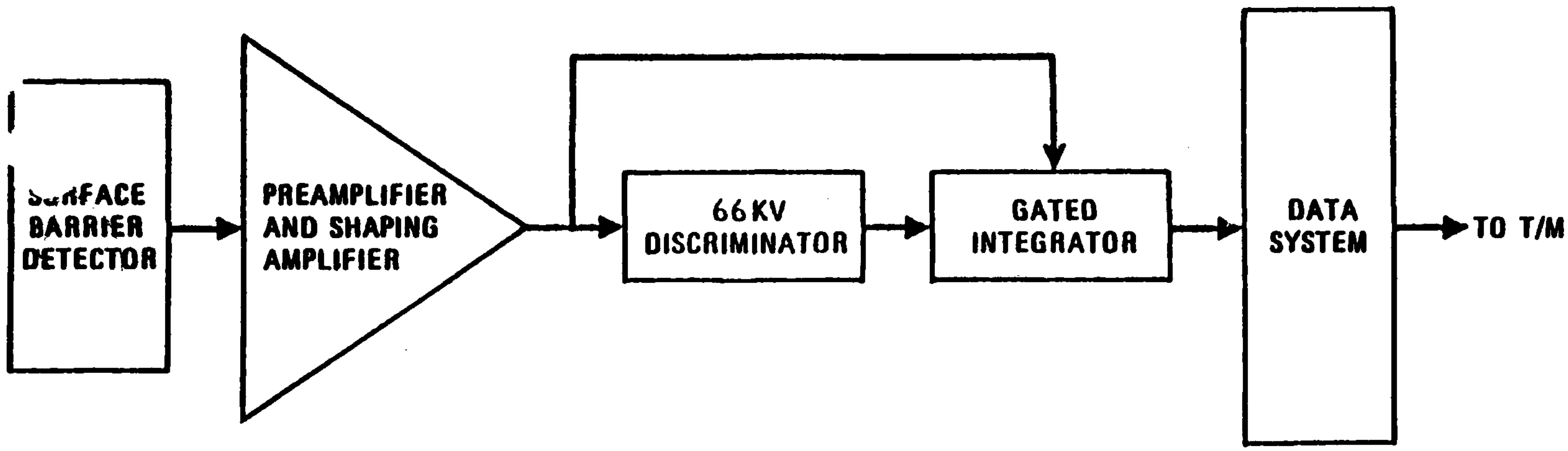

FIGURE 2.   Block diagram of the electronics system.

volume of the detector produces a number of electron-hole pairs which is directly proportional to the amount of energy deposited in the detector. The charges are collected by the detector electrodes and produce a pulse at the amplifier output. For purposes of the following discussion, it is important to note that both the amplitude and the area (integral over time) of the pulse are directly proportional to the energy which the particle deposits in the detector.

An integral discriminator, with a threshold corresponding to deposited energy of 66 keV is used to analyze the pulse-height spectrum of signals produced by protons, electrons and photons (primarily bremsstrahlung) entering the detector. Since photons interact with the detector material by producing fast electrons which in turn lose a part or all of their energy by producing ion pairs, pulses produced by gamma rays are the same as those produced by primary electrons and will be referred to as electron pulses.

The threshold of 66 keV was selected on the basis of detector noise present when the entire package is operated at the planned temperature of less than 40° C. In order to match parent instrument redundancy, there are two identical units mounted in the Mission 46B package. Individual pulses are counted in scaling registers which are read out and reset by the telemetry system once every thirty-two seconds.

In measuring the accumulated dose use is made of the fact that the area as well as amplitude of individual pulses is directly proportional to the energy which a particle deposits in the active volume of the silicon disc. The gated integrator shown in Figure 2 accepts pulses whose amplitudes exceed the value of the gating threshold of 66 keV. Every pulse meeting the gating criteria is integrated and the resulting charge (area) deposited in a storage capacitor which in general already contains an accumulated charge from preceding signals. Whenever an added increment of charge causes the total charge on the capacitor to exceed 7.6 MeV equivalent of deposited energy, the capacitor is discharged in 7.6 MeV equivalent increments. For each discharge increment, a logic pulse is produced at the integrator output and counted in a storage register.

3. Data System and Telemetry Format

Counts from the registers are read out once every thirty-two seconds by the telemetry system. The registers are never re-set, unless the power is turned off, so that the number of counts read out at any given time represents the total energy in MeV, deposited in the silicon active volume during the entire mission. The data system contains the storage registers where counts from the dose-monitor channel are accumulated, and shift registers for temporary storage of data during readout. It also serves as the interface with the spacecraft telemetry system.

The dose-monitor storage register has a capacity of 36 bits each. The counts are accumulated directly in binary code, so the total capacity of each dose-monitor channel is 2^{36} counts or 6.87×10^{10} counts. Each count corresponds to 2.7×10^{-6} rad as determined by the calibration data. The maximum dose capacity is 1.85×10^{5} rads. The maximum and minimum measurable dose rate is determined by maximum discharge pulse rate (10^{5} pulse/sec) and the system leakage current (1 pulse/500 sec) respectively. The maximum measurable dose rate is 0.27 rads/sec. The minimum detectable dose rate is 5.4×10^{-9} rads/sec (0.17 rad/yr).

4. Calibration and Testing

As was explained previously, each dosimeter count represents 7.6 MeV of energy deposited in the active volume of silicon. Since the precise value of the active volume is not known, it is necessary to calibrate the instrument by exposing it to a radiation flux and measuring the dose with a laboratory standard. A calibration was performed with .86 mCi ^{60}Co sources at The Aerospace Corporation. The source dose rate as a function of distance from the source is given in Figure 3. Comparing measurements by a laboratory surveymeter and a series of TLD detectors. All three units have essentially the same calibration constant. The calibration data are summarized in Table 1. The instrument packages were subjected to a 3-axis vibration test for 3 minutes at a 14.2 g rms level. There were no mechanical failures or instrument malfunctions. Prior to calibration the instrument packages were successfully thermal cycled between ± 25° C.

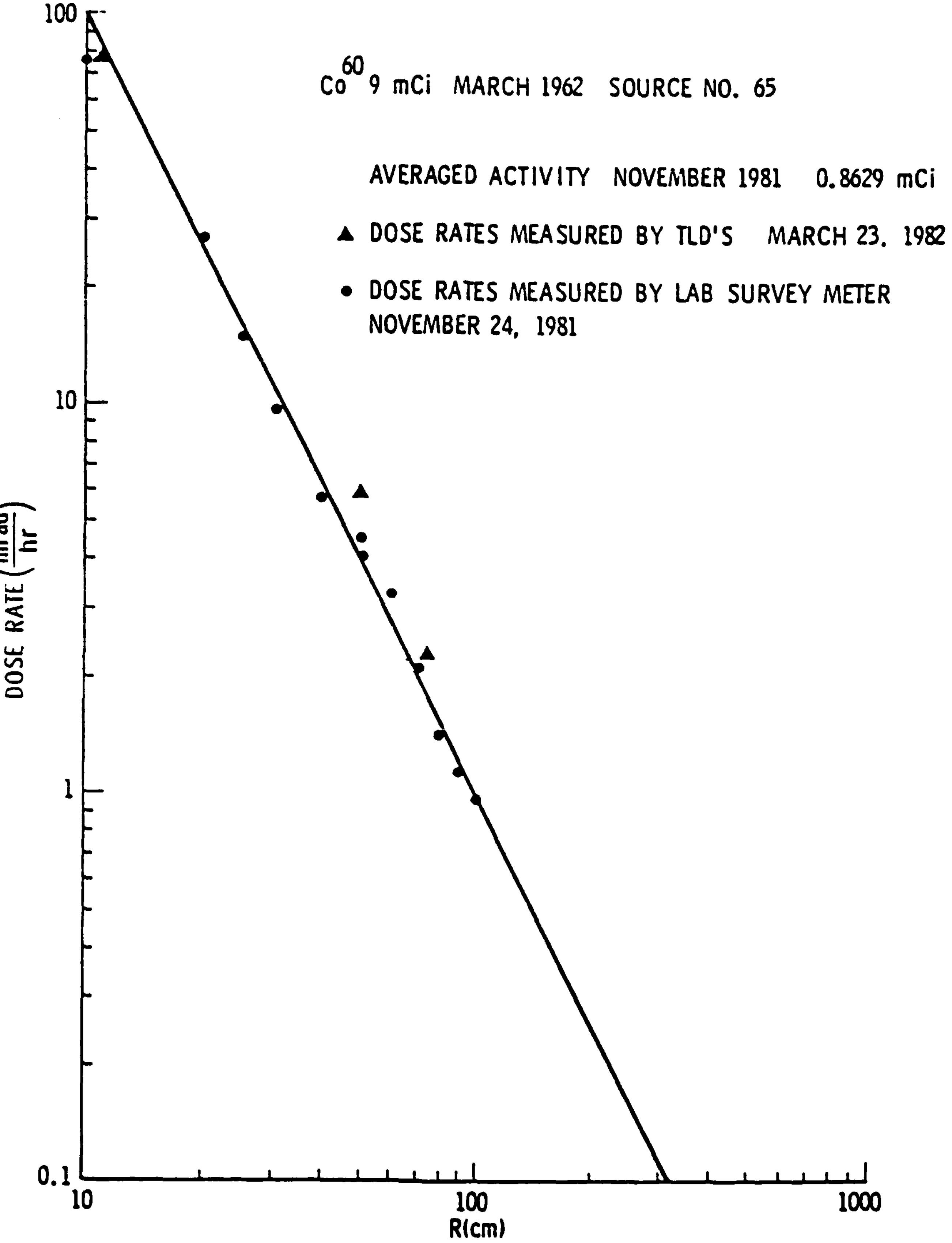

FIGURE 3. Co^{60} Source Calibration Data

TABLE 1. Dosimeter Calibration Data

Unit	Calibration Constant Dose Rate $\left(\frac{\text{m rad}}{\text{pulse}}\right)$	Threshold (keV)	Energy/Output Pulse (MeV)	Power	Weight
1B	2.745×10^{-3}	66	7.6	12 ma at 30V	1 lb., 1.5l
3A	2.725×10^{-3}	66	7.6	12 ma at 30V	
2B	2.677×10^{-3}	66	7.6	12 ma at 30V	

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LABORATORY OPERATIONS

The Laboratory Operations of The Aerospace Corporation is conducting experimental and theoretical investigations necessary for the evaluation and application of scientific advances to new military space systems. Versatility and flexibility have been developed to a high degree by the laboratory personnel in dealing with the many problems encountered in the nation's rapidly developing space systems. Expertise in the latest scientific developments is vital to the accomplishment of tasks related to these problems. The laboratories that contribute to this research are:

Aerophysics Laboratory: Launch vehicle and reentry aerodynamics and heat transfer, propulsion chemistry and fluid mechanics, structural mechanics, flight dynamics; high-temperature thermomechanics, gas kinetics and radiation; research in environmental chemistry and contamination; cw and pulsed chemical laser development including chemical kinetics, spectroscopy, optical resonators and beam pointing, atmospheric propagation, laser effects and countermeasures.

Chemistry and Physics Laboratory: Atmospheric chemical reactions, atmospheric optics, light scattering, state-specific chemical reactions and radiation transport in rocket plumes, applied laser spectroscopy, laser chemistry, battery electrochemistry, space vacuum and radiation effects on materials, lubrication and surface phenomena, thermionic emission, photosensitive materials and detectors, atomic frequency standards, and bioenvironmental research and monitoring.

Electronics Research Laboratory: Microelectronics, GaAs low-noise and power devices, semiconductor lasers, electromagnetic and optical propagation phenomena, quantum electronics, laser communications, lidar, and electro-optics; communication sciences, applied electronics, semiconductor crystal and device physics, radiometric imaging; millimeter-wave and microwave technology.

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Materials Sciences Laboratory: Development of new materials: metal matrix composites, polymers, and new forms of carbon; component failure analysis and reliability; fracture mechanics and stress corrosion; evaluation of materials in space environment; materials performance in space transportation systems; analysis of systems vulnerability and survivability in enemy-induced environments.

Space Sciences Laboratory: Atmospheric and ionospheric physics, radiation from the atmosphere, density and composition of the upper atmosphere, aurorae and airglow; magnetospheric physics, cosmic rays, generation and propagation of plasma waves in the magnetosphere; solar physics, infrared astronomy; the effects of nuclear explosions, magnetic storms, and solar activity on the earth's atmosphere, ionosphere, and magnetosphere; the effects of optical, electromagnetic, and particulate radiations in space on space systems.

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The detectors are passively cooled in order to keep the system noise well below the electronic energy threshold set at 66 keV. A backup instrument also

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